PRACTICAL SUGGESTIONS REGARDING SOURCES OF RADIANT ENERGY FOR MEDICAL USES*

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The primary natural source of ultraviolet radiation is the sun. Approximately five per cent of this incandescent body's radiation is ultraviolet. The ultraviolet intensity at the earth's surface depends on a number of factors including time of day, time of year, latitude, elevation above sea level, atmospheric turbidity and thickness of the ozone layer.

The use of the sun as a calibrated source requires a careful observance of these factors. If a non-selective radiometric measuring device is used for determining the intensity of radiation, then the value of sky radiation versus sun radiation must be used in maintaining the position of the subject. A selective system of filters or a monochromater combined with a non-selective detector will give the energy of the spectrum in narrow band widths.

The exact duplication of the solar spectrum in its entirety presents a difficult problem (see Table 1). Arcs radiate sufficient ultraviolet but too little infrared in proportion. The available incandescent sources have spectra differing from the sun in two respects: first, for the same amount of visible energy they radiate less ultraviolet; second, for the same amount of visible energy they radiate relatively more in the far infrared. Accordingly, sunlight can only be duplicated by adding ultraviolet to and subtracting long-wave infrared radiation from the spectrum of an incandescent body. This is achieved practically by a combination of arcs and incandescent lamps with suitable filters to remove the far infrared and the ultraviolet shorter than a wavelength of 2900 Å.

The results of past research projects concerned with erythemal and tanning effects indicate that only a short range of the ultraviolet section of the solar spectrum is needed for making these tests, but it is always important to keep in mind that some other parts of the solar spectrum may contribute as operative or causative factors in this field.

An economical and practical approach to the problem is to use a source which qualifies as an artificial source of sunlight as designated by the Council of Physical Therapists in the *Journal of the American Medical Association*, **102:** 42, 1934. "At a specified distance the source emits ultraviolet radiation not differing essentially from that of the clearest weather, midday, midsummer, midlatitude, sea level, natural sunlight in total intensity and in spectral range of wavelengths extending from about 2900 Å to and including 3130 Å and does not emit an appreciable amount of radiation of wavelength shorter than 2800 Å. At a distance of 61 cm. from the front edge of the reflector the intensity must be strong enough to give a minimum perceptible erythema in one hour and at a closer distance give a MPE in 15 minutes without heat burn. The intensity shall be equal within a circle ten cm. in diameter lying in a plane at right angles to the source at the specified operating distance."

Many commercial sources of this type are available, and they are simple to manipulate. Some of the test results would have immediate application and could be correlated to existing therapeutic methods. M. Luckiesh of Nela Park has described the use of such a source combined with organic filters to measure erythemal and tanning effects on a broad band basis. The results of his valuable research could be used to correlate with tests made with various inhibitors, and the correspondences and contrasts in these results could lead to refinements in theory and developments in therapeutic method.

The fact that ultraviolet radiation is valuable as a research tool in pigmentation studies requires that more consideration be given to the development of a source. The radiation resonance effect of strong erythema with minimum tanning results at 2500 Å, no erythema or tanning at 2800 Å and strong erythema and strong delayed tanning at 2967 Å which tapers off to a weak immediate tanning effect alone at 3100 Å and above is a genuine research challenge.

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Presented at the Brook Lodge Invitational Symposium on the Psoralens, sponsored by The Upjohn Company, Kalamazoo, Michigan, March 27–28, 1958.

TABLE 1

Comparison of Performance at Various Wavelengths between Sunlight and a Number of Available Artificial Sources

Center Wave-length	Sun	Sunshine C carbon 30 amp. 50 u. AC	Sunshine carbon 60 amp. 50 u. AC	"W" carbon 80 amp. 60 volt	G. E. AH 6 Mercury	Hanovia Xenon, Hg.
2950	8	10	30	412	163	43.2
3000	29	14	33	445	226	54.6
3100	110	19	52	330	350	75.2
3200	240	26	80	233	136	38.4
3300	380	40	113	240	144	48.4
3400	420	38	112	238	80	39.2
3500	460	44	116	347	80	40.8
3600	550	58	183	720	158	154.0
3700	590	80	241	560	235	40.0
3800	590	127	413	750	124	35.2
3900	730	163	518	750	80	29.0
4000	1090	160	468	570	240	108.8

(Microwatt/cm^2 at 1 meter, 25,000 microwatt—sec/cm^2 for MPE of 2967 Å. 2.5 $\times$ MPE = vivid = moderate tan.)

Some types of selective skin receptors would seem to be present in this particular phenomenon of radiation on matter. The energy could be transferred as molecular heat vibration, an ionic or electronic displacement which could change the conduction or ionizing potentials, some bonding energy could be readjusted to give a physicochemical change or one of the photo effects could be involved, such as the change in fluorescence as noted by Luckiesh. All of these effects require a high intensity, narrow wave band, continuous source of ultraviolet radiation for critical examination. The most efficient and useful sources of ultraviolet are the arcs. The spectrum of most arcs is chiefly due to the discharge through the gas or vapor and so is usually of the line or band type. The gases and vapors used include such diverse substances as hydrogen, helium, argon, neon, krypton, xenon, mercury, cadmium, zinc, tellurium and magnesium.

A survey of commercially available arcs, from companies such as Hanovia, National Carbon, Adam Hilger, Beckman, Jarrell Ash, Bausch & Lomb and Macbeth, shows a generally inadequate intensity for narrow wave band use. Correspondence with the Charles F. Kettering Foundation and Dr. Edlefsen led to the development of a high voltage hydrogen arc of an improved model similar to that described by Lawrence and Edlefsen in *Review of Scientific Instruments,* **1:** 45, 1930. The destructive tests conducted with this arc indicated an intensity of continuous ultraviolet from 2300 to 4000 Å approximately three times more intense than any available source. The outstanding drawback with this radiation source is its short irregular life due to electrode problems and the expense of fabricating duplicates.

The monochromater is also an important component of the source. Band widths of 50 to 100 Å of high intensity ultraviolet should give the resolution needed to differentiate the variabilities in pigmentation resulting from ultraviolet radiation. The choice of monochromater depends upon the properties which are thought to be most important, such as chromatic aberration, spectral purity, transmission, scattered light, numerical aperture, band width, etc. The L254-150 quartz monochromater manufactured by the Gaertner Scientific Corporation has quite satisfactory transmission at the short wavelengths. This is a high speed instrument with sufficient dispersion. The synchronized mechanism operated by a drum permits accurate and convenient focusing of the telescope and collimater. The Bausch & Lomb monochromater uses a plane grating as the dispersing device. This grating is blazed for the ultraviolet in the first order. This monochromater has an efficiency of 65 per cent at 2650 Å. The high linear dispersion and achromatic properties, since only reflecting optics are used, are desirable features of this instrument. The Van Cittert type of prism monochromater, described in a research paper from the University of California is a flexible, versatile instrument and, with the two rotating tables and reciprocating slit system, gives good control of the wavelength with a high level of transmission.

A non-selective ultraviolet detector is the other instrument needed to complete the source system. The two main types of physical detectors are radiometric and photoelectric. The radiometric ones are non-selective and depend on heating effects. The thermopile depends for its operation on the EMF generated when the junction between two dissimilar metals is heated. The radiometer depends on the deflection of a very light vane suspended by a fine quartz fiber. The bolometer device has been incorporated into some very useful instruments. Its use as a sensitive Wheatstone bridge gives an accurate response to minute radiant potentials.

The metallic type phototube, with a balancing circuit and filters, is a selective detecting instrument for ultraviolet which can be constructed sturdy enough for general use in contrast to the radiometric devices which are quite sensitive but delicate. It would be best if a radiometric device could be available for calibration and initial lining up of sources. The day by day measurement could then be made with a calibrated photoelectric device.

In summary, the basic requirements for a biologically effective radiation source might be listed as follows:

1. Energy production at a measurable rate.
2. Constant energy with linear controllable variability over a wide range.
3. Reproducible as to spectrum and intensity.
4. Biological effective spectral distribution.
5. Sufficient energy over the required spectrum in 50 Å band widths with at least a 5 mm. aperture.
6. Adequate operating life for 200 hour usage.
7. Overall design for ruggedness and some degree of portability.
8. Economical initial and replacement costs.
9. Simplicity of operation.
10. Uniformity of adaptability to general biological problems which would lead to a greater co-ordination of quantitative results.
11. Calibration methods for standardizing the quantitative results.
    a. Bureau of Standards lamp for detector calibration.
    b. Use of mercury arc source with standard line 2967.28 Å to designate spectrum range.
    c. Absorption spectrum of all optical elements such as filters, prisms and lenses as recorded by spectrophotometer.